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MECHANIZATION OF HOUSING SOLID WASTE COLLECTION.(U)
AUG 77 C J WARD, D L CANNON
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CIVIL ENGINEERING LABORATORY
NAVAL CONSTRUCTION BATTALION CENTER
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Increased cost of solid waste handling and disposal at Navy Shore Facilities has set a high priority on development of new methods and equipment that can reduce expenditures. One technique often used to cut costs is to automate labor-intensive tasks. Development of a mechanized, residential housing collection attachment would eliminate the need for manual loaders. Retrofitting the attachment to existing Navy industrial collection vehicles would eliminate the need for specialized residential collection vehicles. A refuse over

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CONTENTS

INTRODUCTION

Increased costs of solid waste handling and disposal at Navy shore facilities have resulted from new environmental requirements, higher labor and equipment costs, and increases in the quantity of solid waste being generated. This has set a high priority on development of new methods and equipment that can reduce expenditures for solid waste handling and disposal. Additionally, new requirements are being imposed on Navy public works activities by a demand for cost-effective and environmentally acceptable methods and equipment for collection, separation, recycling/recovery, and disposal of material.

To meet these requirements, the Naval Facilities Engineering Command (NAVFAC) tasked the Civil Engineering Laboratory (CEL) to perform advanced development on mechanization of collection of solid waste from Navy residential housing areas. The effort on mechanization of housing collection has as its primary goal the development of an attachment for Navy front-loading, packer-type refuse collection trucks that will permit one-man operation for residential collection.

Successful development of this attachment will reduce and standardize the equipment requirements by permitting existing Navy industrial collection vehicles, which are presently restricted to emptying large storage containers used for base facility waste, to also collect curbside or alley set-outs of wastes generated in family housing areas. Since manpower will also be reduced by permitting one-man operation of residential collection equipment, considerable labor savings will also result.

This report covers the results of the FY-76 and FY-TQ effort, which include the fabrication, assembly, functional testing, and laboratory testing (truck stationary) of the attachment.

Background

The Civil Engineering Laboratory has been tasked to review requirements and to develop systems, procedures, methods, and equipment for solid waste handling and disposal at Naval shore facilities. At present, the majority of solid wastes from Naval facilities are generated at industrial, institutional, and commercial-type facilities. Collection of these solid wastes generally utilizes front-hoisting refuse collection trucks conforming to specification MIL-T-46748C, and employs containers conforming to specification MIL-R-239541. Most facilities have family housing from which solid waste must also be collected. The majority of the facilities have fewer than 1,000 housing units, and, in most cases, the generation from these units amounts to no more than one quarter of

the total solid waste load of the facility. Collection from family housing areas, when performed by Navy civilian employees, is generally by rear-loading, packer-type trucks conforming to specification MIL-T-2452E, which are manned by a driver and one or two loaders. Metal garbage cans, conforming to specification RR-C-82E, are made available at each family unit by the Navy for the collection of solid wastes.

Analysis of Navy needs indicates* a high priority on improving the method for collection of family housing waste by the development of an attachment for use with existing front-loading collection trucks. Successful development and implementation of this proposed attachment will: (1) reduce and standardize equipment requirements by permitting existing Navy front-loading collection vehicles, presently used to empty large industrial-type storage containers, to collect curbside or alley set-outs of wastes generated in family housing areas; and (2) reduce operating costs in manpower and incidents of personnel injury.

Mechanized residential collection technology is currently under development by a number of commercial organizations. Most of these developments are at the stage where prototypes are being evaluated operationally. However, with a few exceptions, these are oriented toward a single type of standard container and special purpose collection vehicles with capacities in excess of the requirement for housing collection at most military facilities. By contrast, the work reported herein is oriented toward development of an attachment for existing Navy vehicles that can service most any size or shaped container including bags or boxes.

The previous study* of the need for an automated residential refuse collection system for Navy use indicates the design criteria for development should be as summarized in Table 1. Also summarized in Table 1 are the laboratory test results.

Accomplishments to Date

A refuse attachment was conceived, and a small working model was constructed for study. A full-scale attachment was designed, fabricated and assembled, and engineering drawings were prepared. A used industrial refuse truck was modified as necessary for installing the attachment and the complete system was laboratory-tested. Modifications were made to the attachment in preparation for field tests.

DESCRIPTION OF ATTACHMENT

Figure 1 illustrates the attachment being developed for Navy front-loading, packer-type refuse collection trucks (MIL-T-46748C). As shown,

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*Civil Engineering Laboratory. Contract Report CR76.001: Evaluation of Mechanized Collection Systems and Development of Criteria for Prototype Refuse Collection Truck Attachment for Navy Housing Collection, SCS Engineers, Long Beach, Calif., Jul 1975. (Contract N68305-74-C-0014)

the pickup mechanism (called the "hand") consists of a rigid thumb with two fingers. As presently designed, a single rotary actuator controls both fingers of the hand such that one finger grabs a filled container while the other releases an empty one.

The complete system, excluding hydraulic power and electrical controls, is configured as a single unit (Figure 2). It can easily be installed on or removed from the existing forks on the front of the truck in 5 to 10 minutes, making the unit portable and the truck compatible with heavy industrial as well as residential collection. The truck requires only the installation of the additional cab controls and provision of electric and hydraulic connections for conversion (Figures 3 and 4). No significant modification to the truck was required.

Pickup Mechanism Concept

The key component conceived for the attachment is the refuse container pickup mechanism which is configured so that it can pick up all normal sizes and shapes of trash containers (including bags and boxes) and hold each firmly enough for impact dumping without damaging the container. The configuration of the human hand with its thumb and fingers prompted the design. Just as the human hand is capable of picking up and holding objects of different sizes and shapes, this mechanical hand (Figure 5) can grasp and firmly hold rectangular blocks, tapered containers, and even bundles, such as filled plastic bags. It is important to note the large number of pressure pads used to grasp a container. This distributes over a large area the force required to firmly hold a container, thereby minimizing the probability of damaging it. The pressure forces are controlled by limiting the maximum tendon pull with a pressure control valve on the actuator.

The arm shoulder joint (Figure 6) that connects the arm to the bin has been designed using common hydraulic actuators for control. It has the needed two angular degrees of freedom normal to a shoulder, but does not include a complex ball or universal joint. The telescoping arm (Figure 7) uses a standard hydraulic ram and is capable for extending as well as moving laterally and vertically when reaching for a container. Once the container is grasped, actuation of the arm dumps into the bin the contents of the refuse container held in the hand. When full, the bin is emptied into the truck using the existing truck controls, (Figure 8). Figure 9 illustrates the chain position modification made for the field tests. Original chain positions (side-mounted) did not distribute the tension loads equally.

When installed, the unit does not extend outside the normal height and width of the truck. Also, the attachment is in full view of the operator and can be elevated, if necessary, when climbing steep hills, driveways, making sharp turns in confined spaces, etc. Consequently, the installation of the attachment does not restrict the maneuverability of the truck or its ability to traverse base roads. Since it can be installed and removed easily and quickly without special tools, it can

be stored in any convenient location and readily transported to the shop when repair or maintenance is required.

Continuous operation is possible with the dual-finger design of the hand. For normal operation, it is expected that the operator will be able to steer the hand to the container and grab it while the truck is in motion. As the hand grabs the full can, the empty one is released simultaneously. The retraction of the arm and the dumping of the container into the bin are rapid and automatic. As a result, it is expected that the truck with the attachment will not have to make a full stop unless obstacles (such as parked cars) dictate or if multiple cans are encountered. The technique might first appear complicated, but actual operator skill required is expected to be minimized due to the hand operation and the controls being identical to those of the human hand and arm.

Attachment Controls

Figures 3 and 10 illustrate the attachment controls to be installed in the truck cab. The functions of these controls are as discussed below.

The normal position of the attachment during transit from one container pickup location to the next is Position A in Figure 11. As the driver approaches the container to be picked up, he presses the cycle control switch located on the end of the joy-stick to initiate the cycle. The arm automatically rotates through Position B to Position C and then begins to extend. During the arm extension, the driver steers the arm and hand toward the container at Position D, using the joy-stick arm control for left/right and up/down motions. When the hand contacts the container at Position D, the driver again depresses the cycle control switch; this stops the extension of the arm and causes one finger of the hand to close and grasp the container, while the other finger opens and releases an empty container to replace the full one being picked up. Then, automatically, the arm lifts the container, retracts into Position C, centers itself in the slot in the bin, and rotates through Position B to dump the container and stop the cycle at Position A. After the container is dumped at Position A, it remains there until the cycle control switch is again depressed to initiate the next cycle. Figures 12 and 13 are pictures of the cycle taken during the functional test. The total time for a complete cycle was tested to be between 17 and 21 seconds.

For safety reasons, the operations of the attachment can be stopped quickly at any time by simply depressing the large on-off switch (to replace the small toggle switch). This freezes the attachment in the position it is in at the time the switch is activated. When the switch is turned on again, the cycle continues from the frozen position.

ELECTRICAL AND HYDRAULIC SYSTEMS

The electrical system is designed to be simple, reliable, and low in cost. All electrical needs are met by 12-volt direct current drawn from the truck battery. No additional regulators, electrical power supplies, or transistors are required. All the electrical parts and components are common devices that are commercially available and designed for long life (Figure 3). The packaged electrical relay unit prepared for field tests is shown in Figure 14. All position sensors are on/off devices that are mechanically actuated (Figure 6). All the electrically controlled hydraulic valves use inexpensive, reliable, solenoid actuators (Figure 15). A quick-release multiple-lead connector (cannon plug) is used to join the cab controls with the attachment. The electrical circuit incorporates inexpensive plug-in relays to facilitate maintenance by replacement rather than repair.

Like the electrical circuit, the hydraulic system is designed around simplicity, reliability, and low cost. Unlike the electrical system, however, the time responses required of the hydraulic actuators for optimum control are difficult to determine in advance. Therefore, all the actuators procured and designed into the prototype attachment have a slightly faster response and higher torque (or force) capability than is believed to be required. Flow restrictors were used in combination with an adjustable relief valve to determine the proper response times to be used in specifying design points in future design work on the hydraulic system.

CONCLUSIONS AND RECOMMENDATIONS

Development work on the attachment completed to date has progressed through the laboratory test (truck stationary) without need for reconsideration or significant alteration of any of the original design objectives listed in Table 1. Therefore, it is recommended that development be continued as follows:

- Complete Memorandum of Procedure for field test and evaluation of refuse collection attachment installed on truck.
- Perform field test and evaluation of refuse collection attachment installed on truck.
- Revise developmental drawings and specifications of refuse collection attachment and truck modifications to incorporate improvements resulting from field tests.

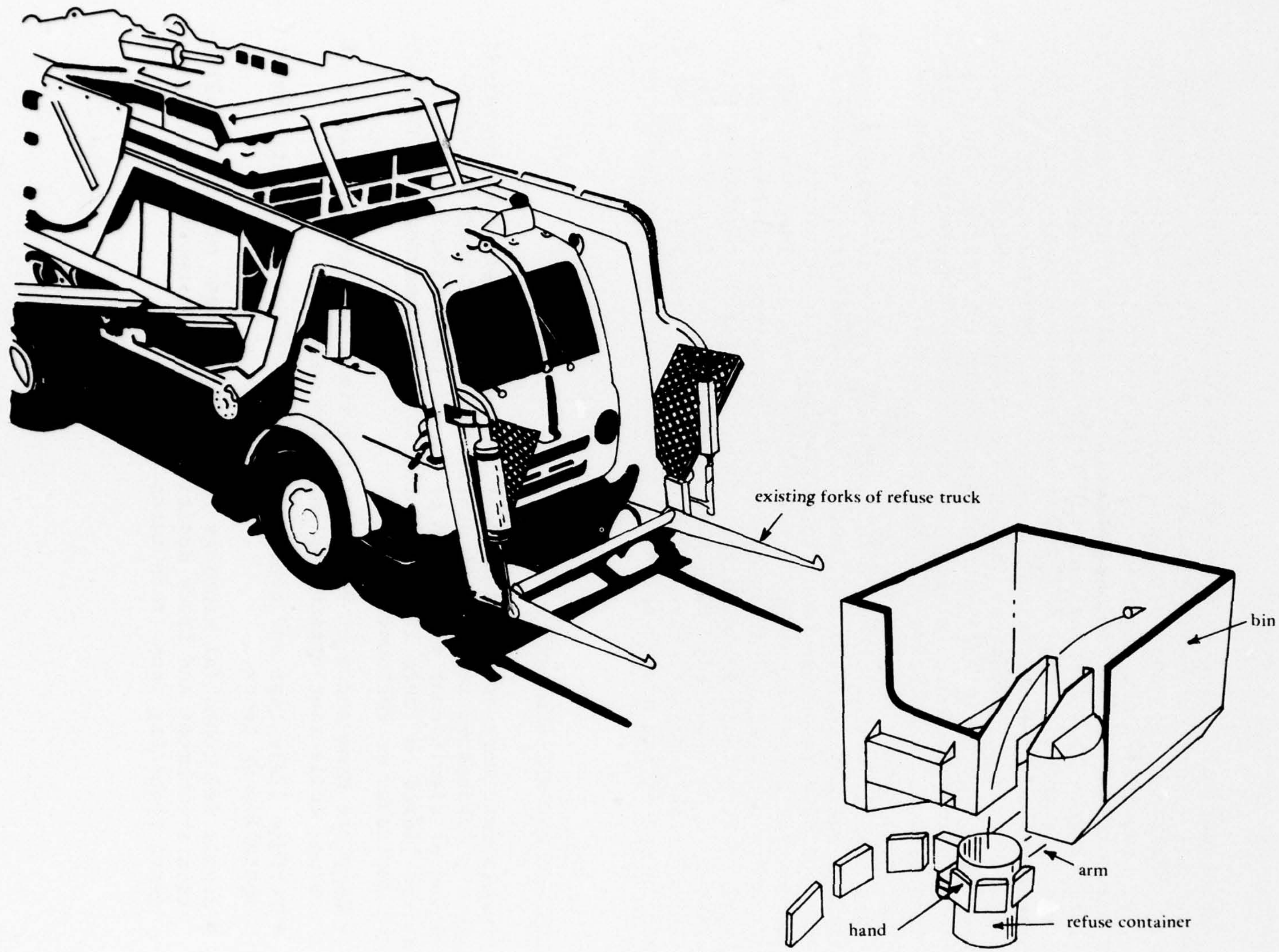

Figure 1. Mechanized refuse collection attachment.

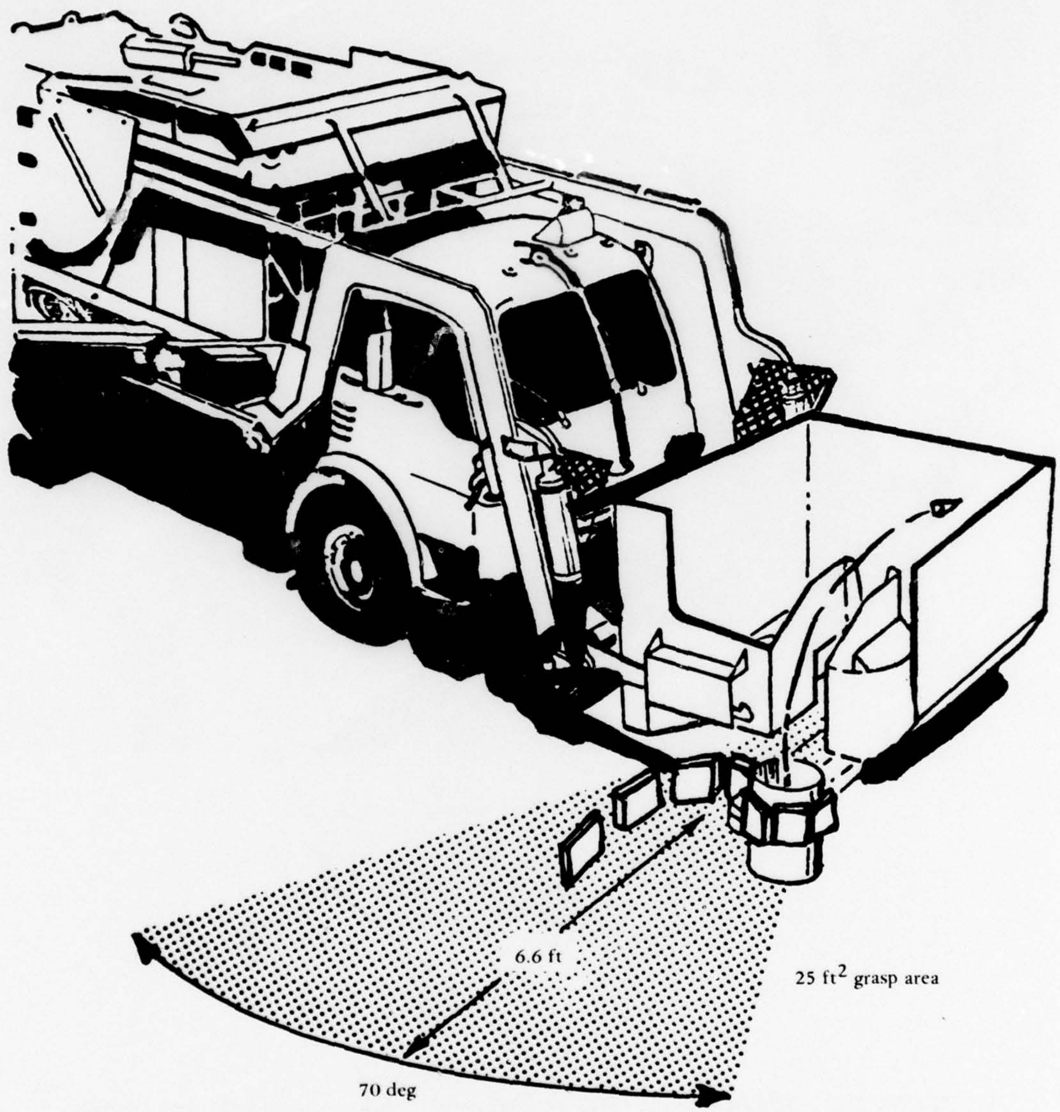

Figure 2. Mechanized refuse collection attachment mounted on existing forks of refuse truck (arm swing of 47 degrees gives 70 degree sector angle of grasp area).

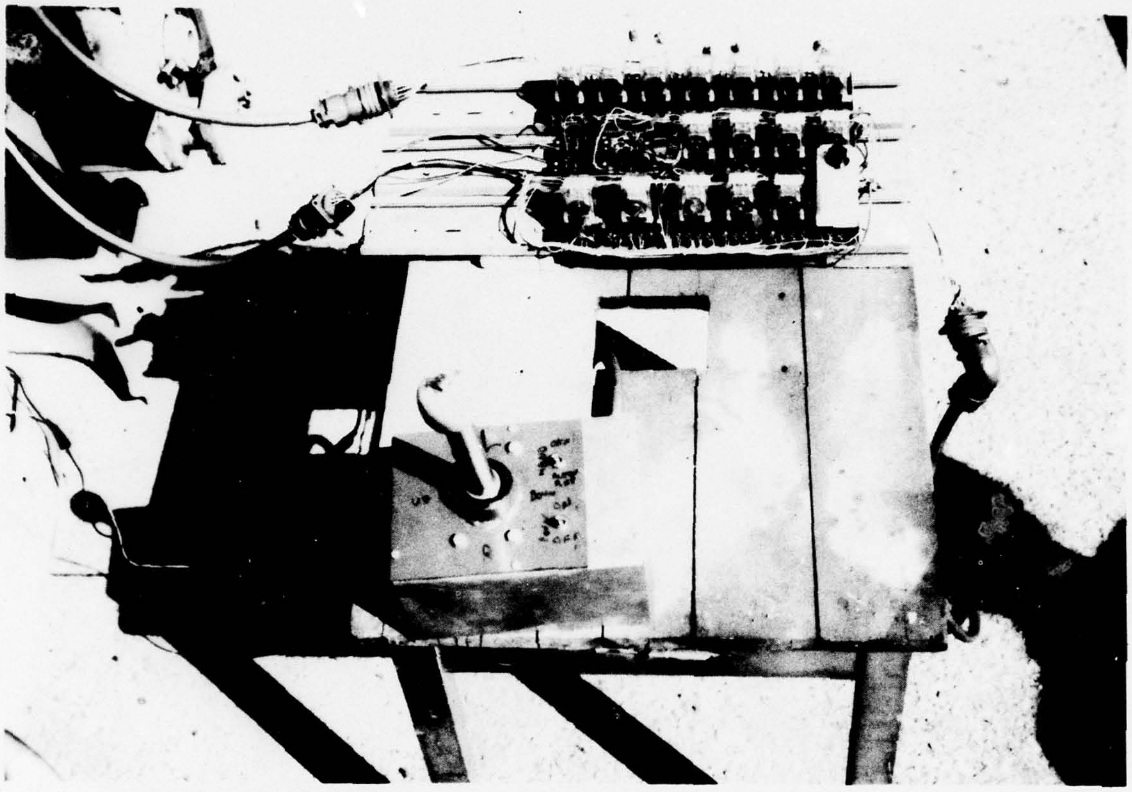

Figure 3. Electrical relays (above) and joy-stick arm control (below) to be installed in truck cab.

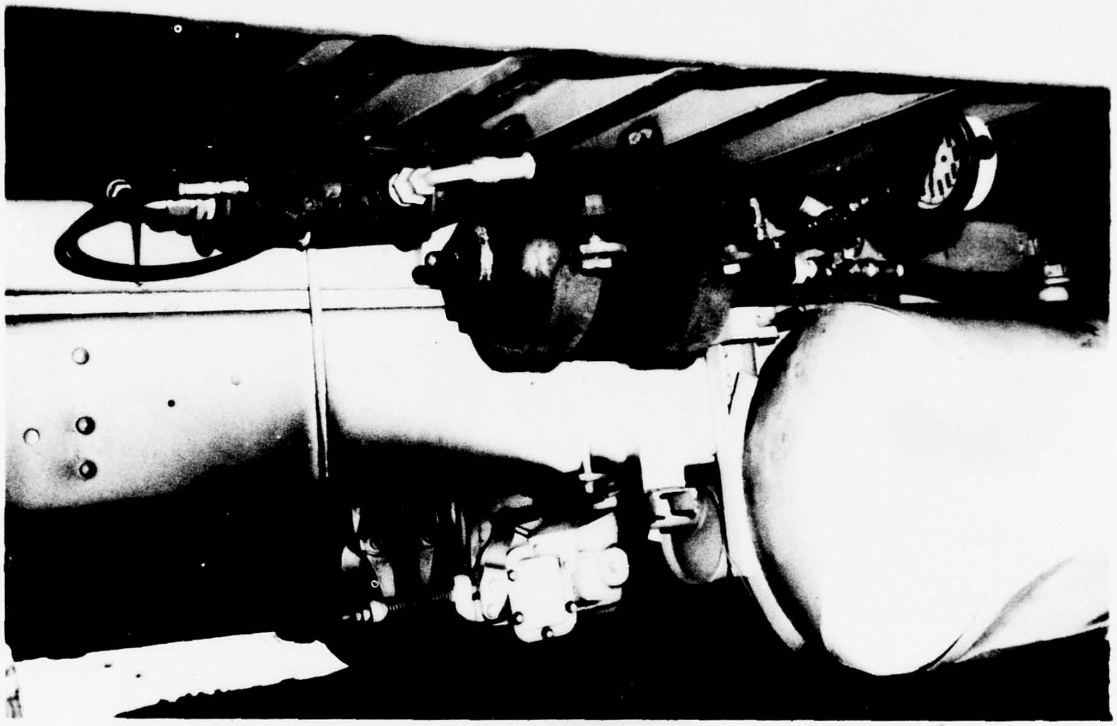

Figure 4. Hydraulic modifications to truck (located below compactor and in front of rear wheels).

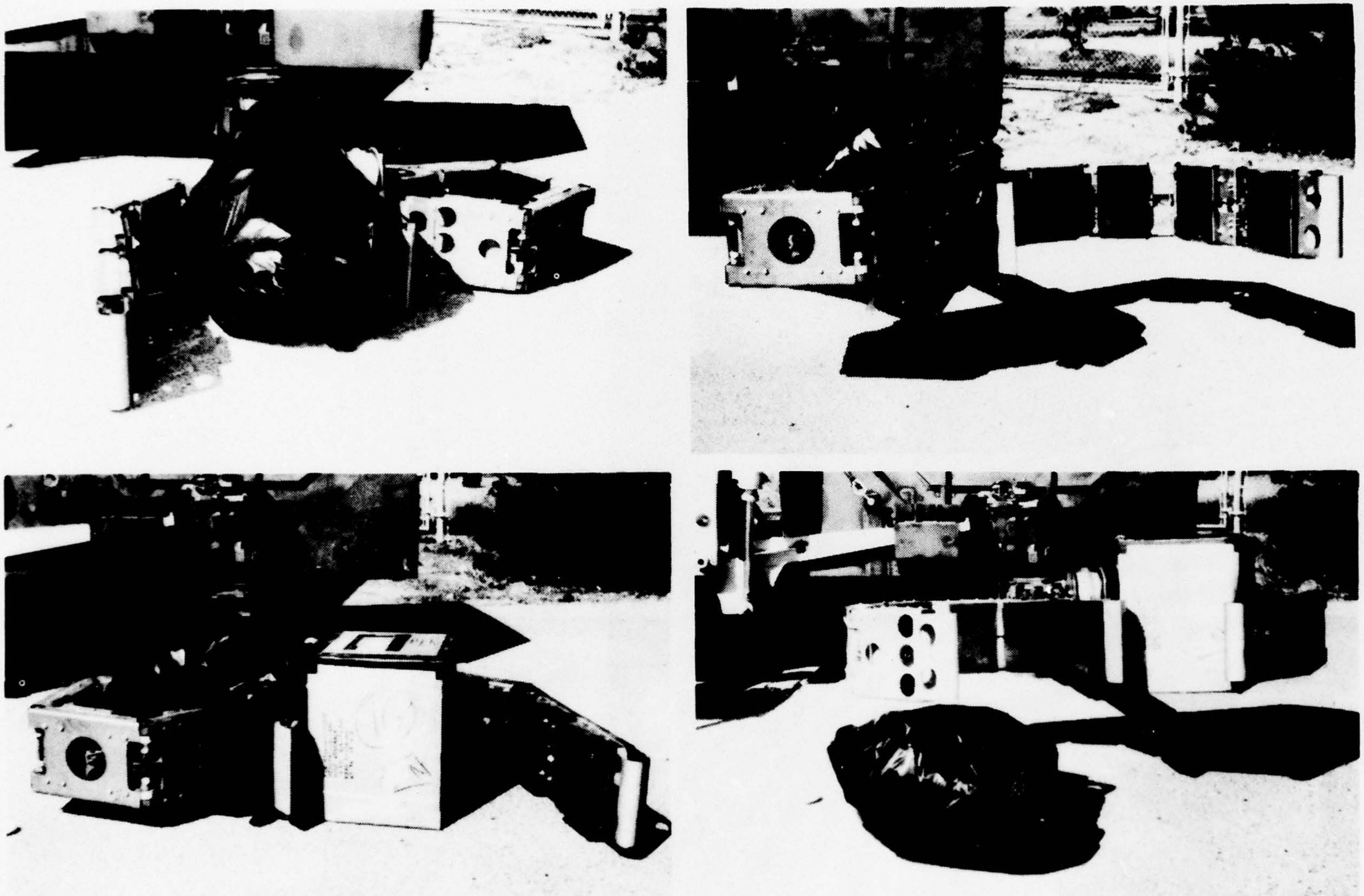

Figure 5. Views of mechanical hand in position: (upper left) hand approaches plastic bag; (upper right) plastic bag grabbed and elevated; (lower left) bag returned and hand positioned for box pick up; (lower right) box grabbed and elevated and plastic bag dropped. (Note: nonreturnable containers would normally be dropped into bin by attachments.)

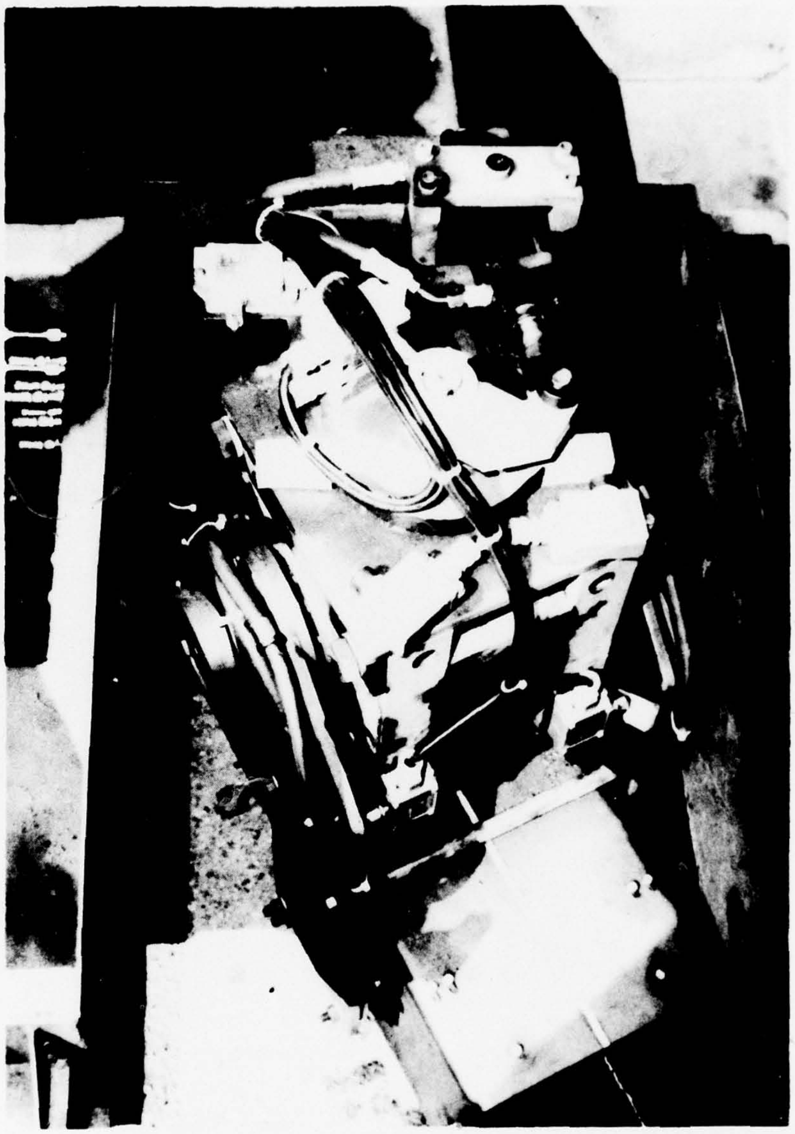

Figure 6. Arm shoulder mechanism.

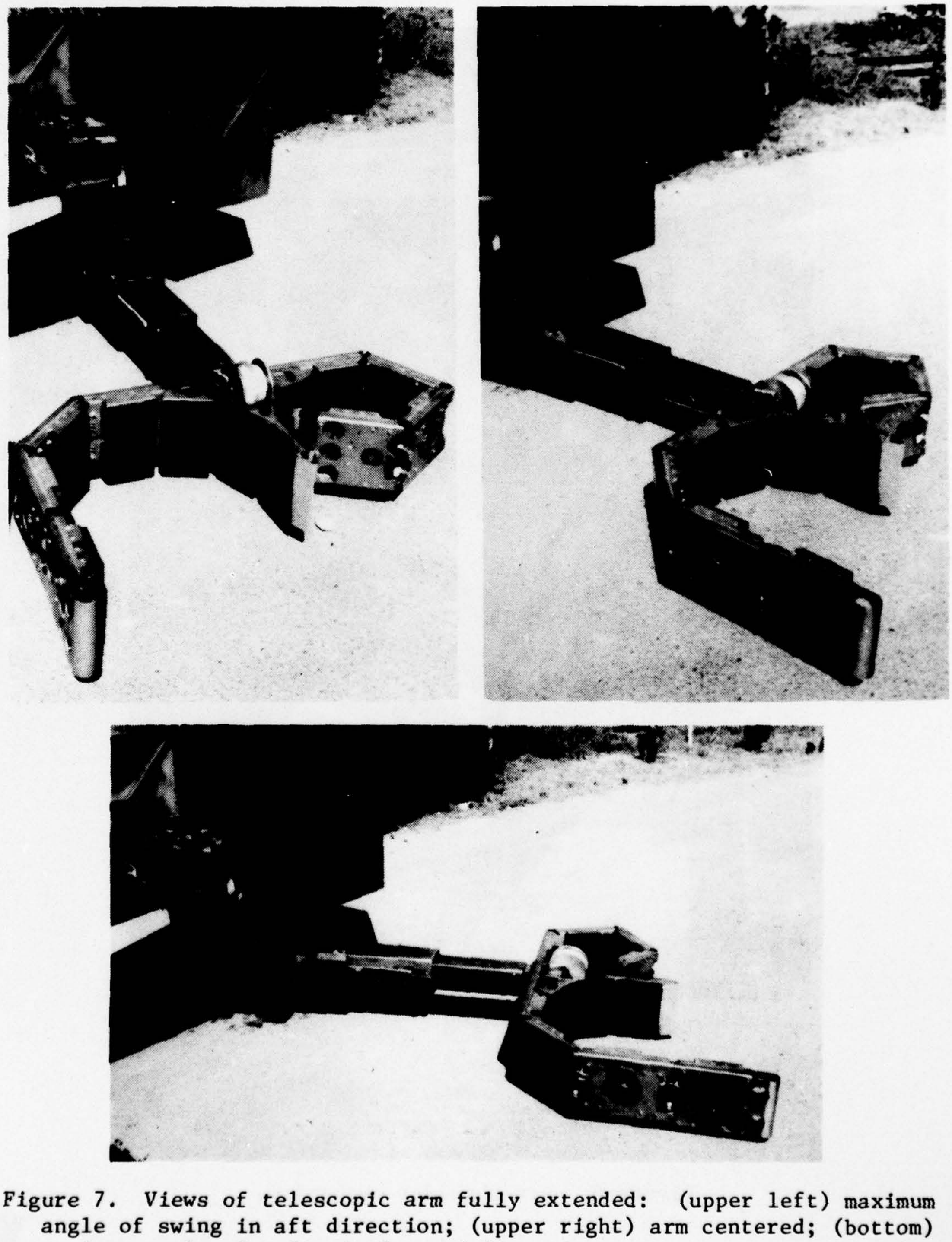

Figure 7. Views of telescopic arm fully extended: (upper left) maximum angle of swing in aft direction; (upper right) arm centered; (bottom) maximum angle of swing in forward direction.

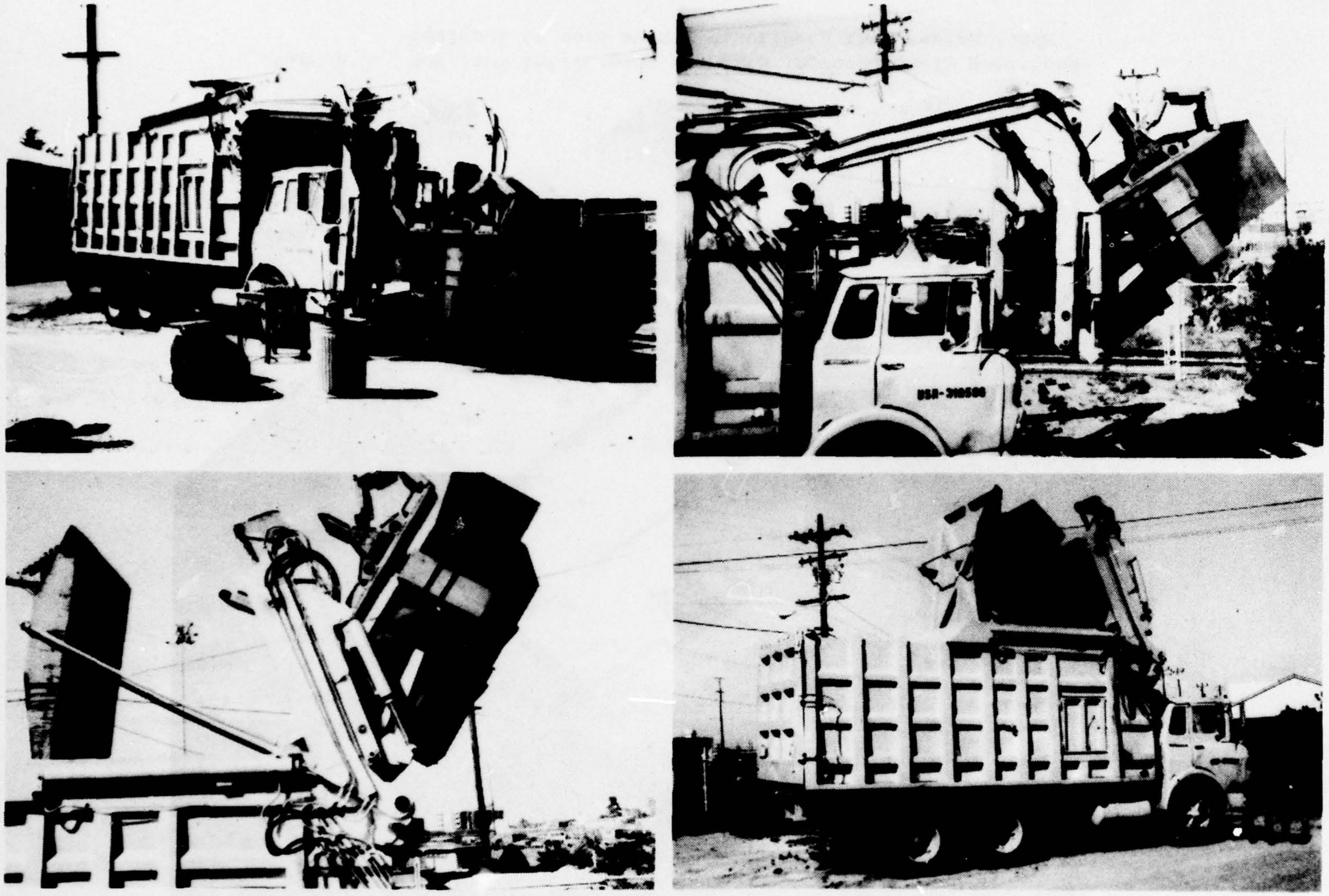

Figure 8. Method of employing attachment: (upper left) normal refuse collection position; (upper right and lower left) intermediate dump positions; (lower right) dump position.

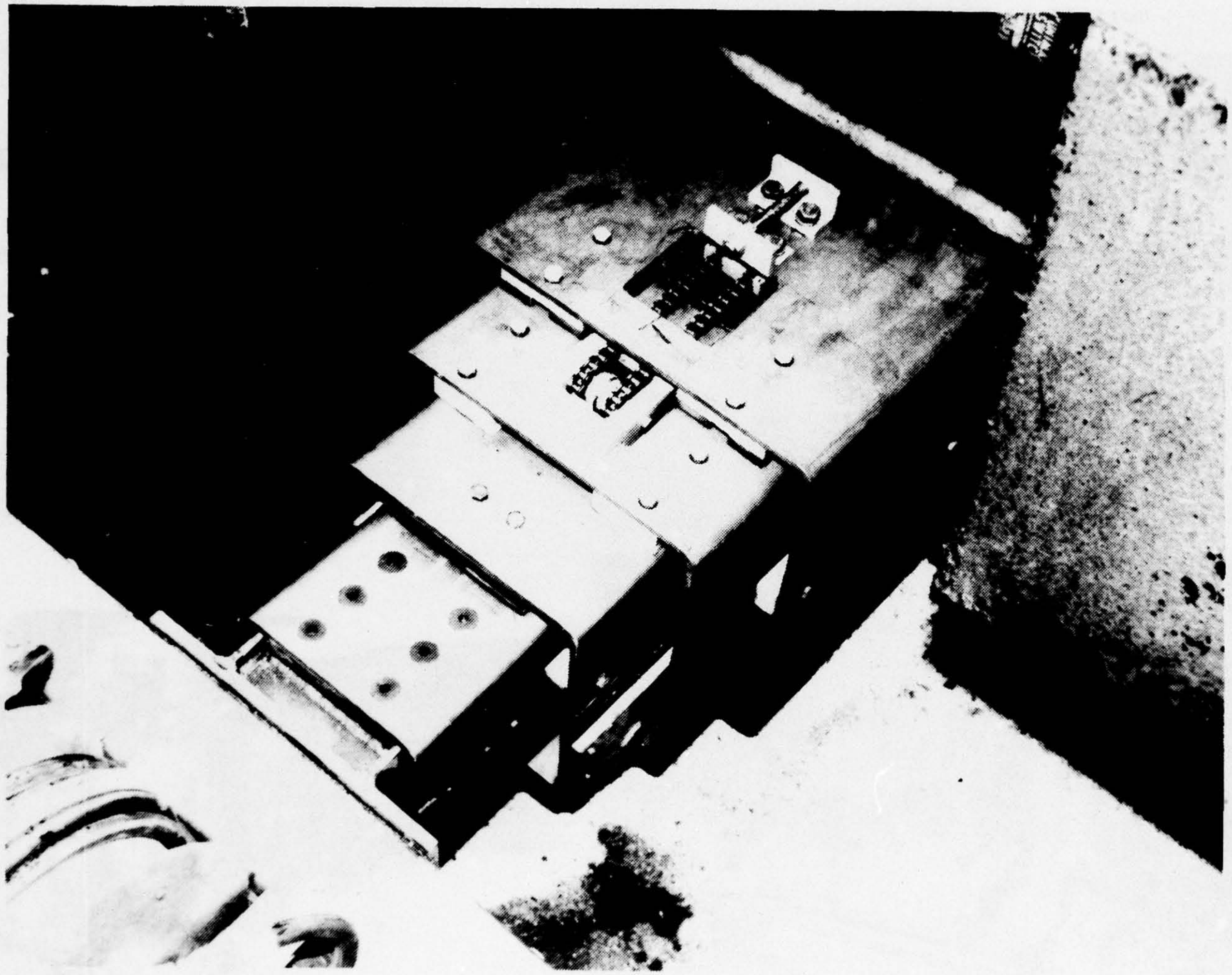

Figure 9. Modified telescoping arm with improved chain positions designed to more evenly distribute the tension loads.

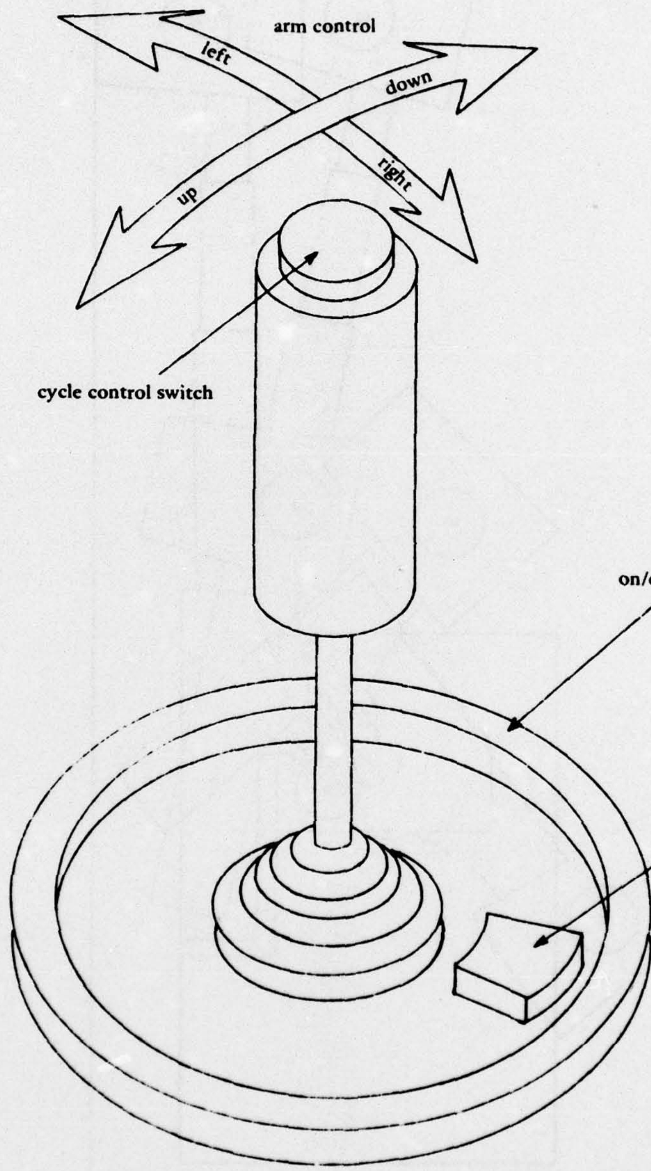

Figure 10. Cab control.

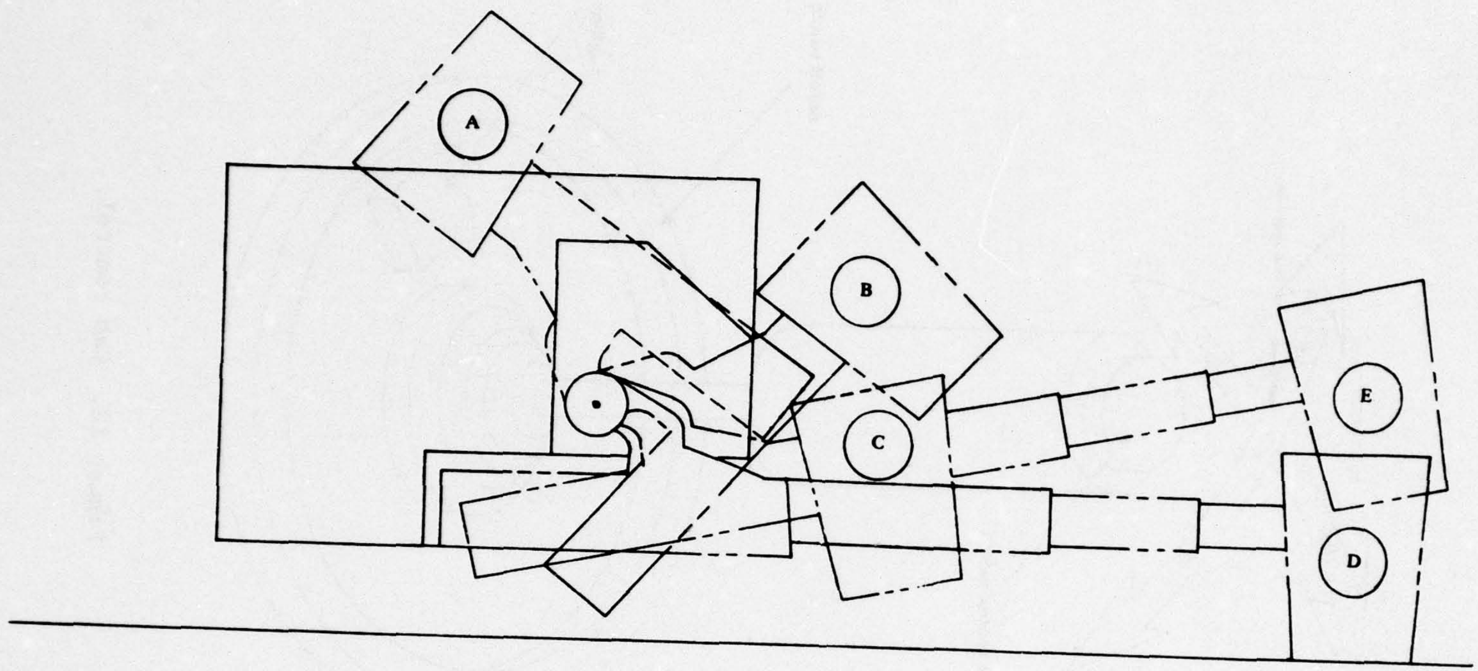

Figure 11. Schematic illustrating operating cycle.

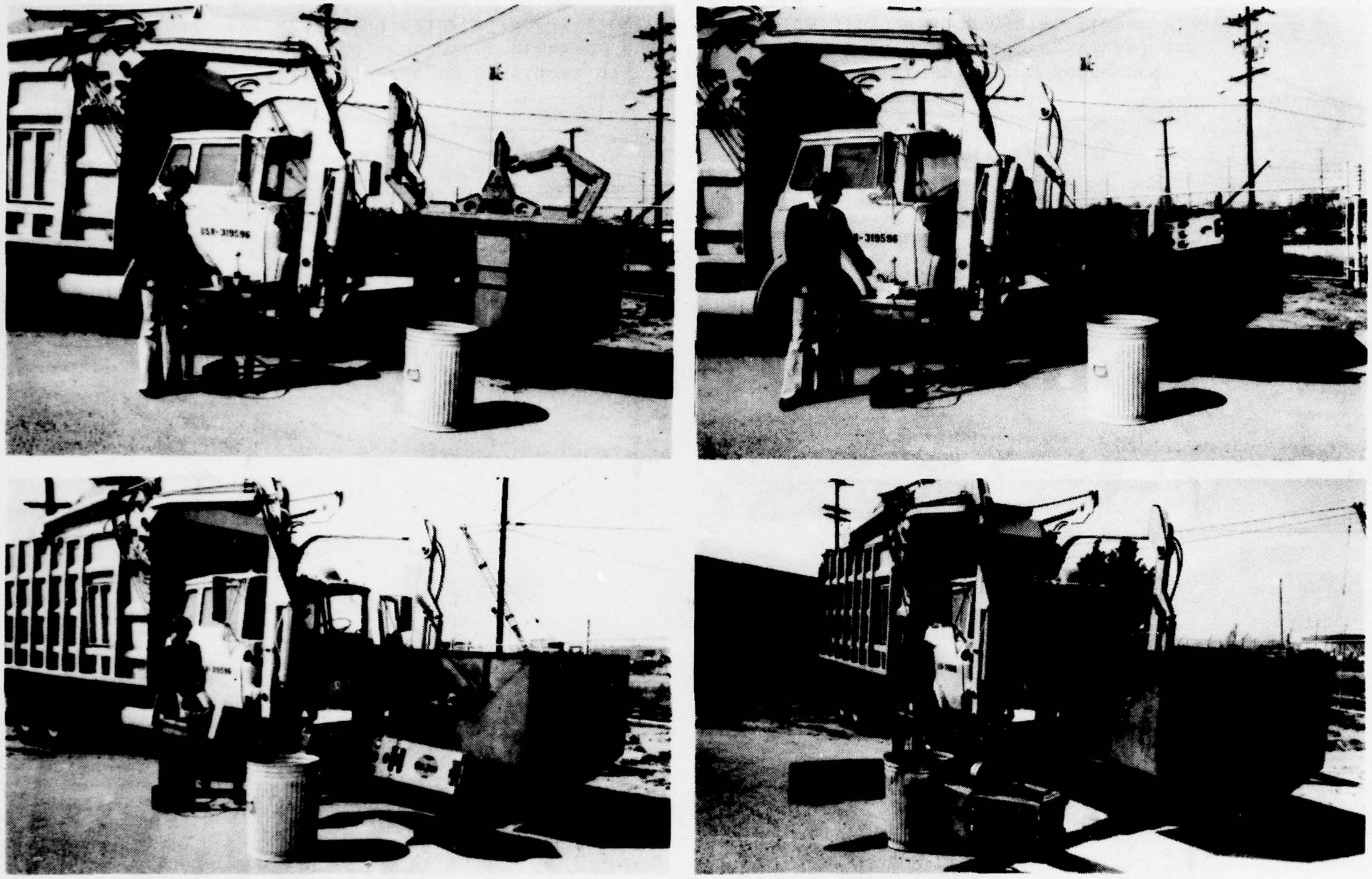

Figure 12. Extension portion of cycle: (upper left) downward aligned rotation, automatic; (upper right) downward rotation just prior to automatic extension; (lower left) arm begins extension, and operator is in control of left-right and up-down arm position; (lower right) hand approaches container.

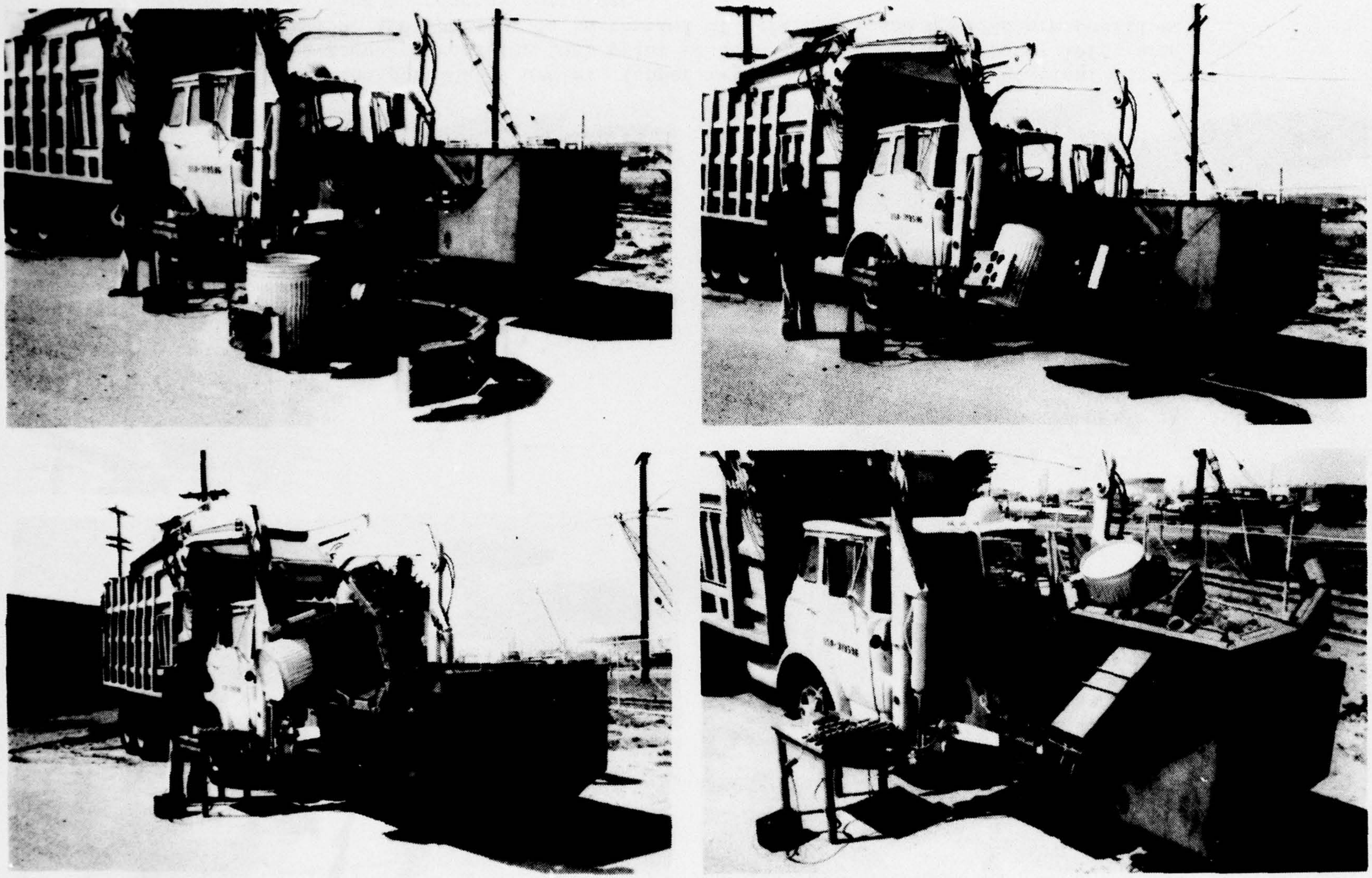

Figure 13. Automatic return positions of cycle: (Upper left) grasp button depressed, extension stopped, container grabbed, and elevation about to begin; (upper right) arm fully retracted and being aligned; (lower left) arm in aligned dump cycle; (lower right) container dumped, and system automatically turned off.

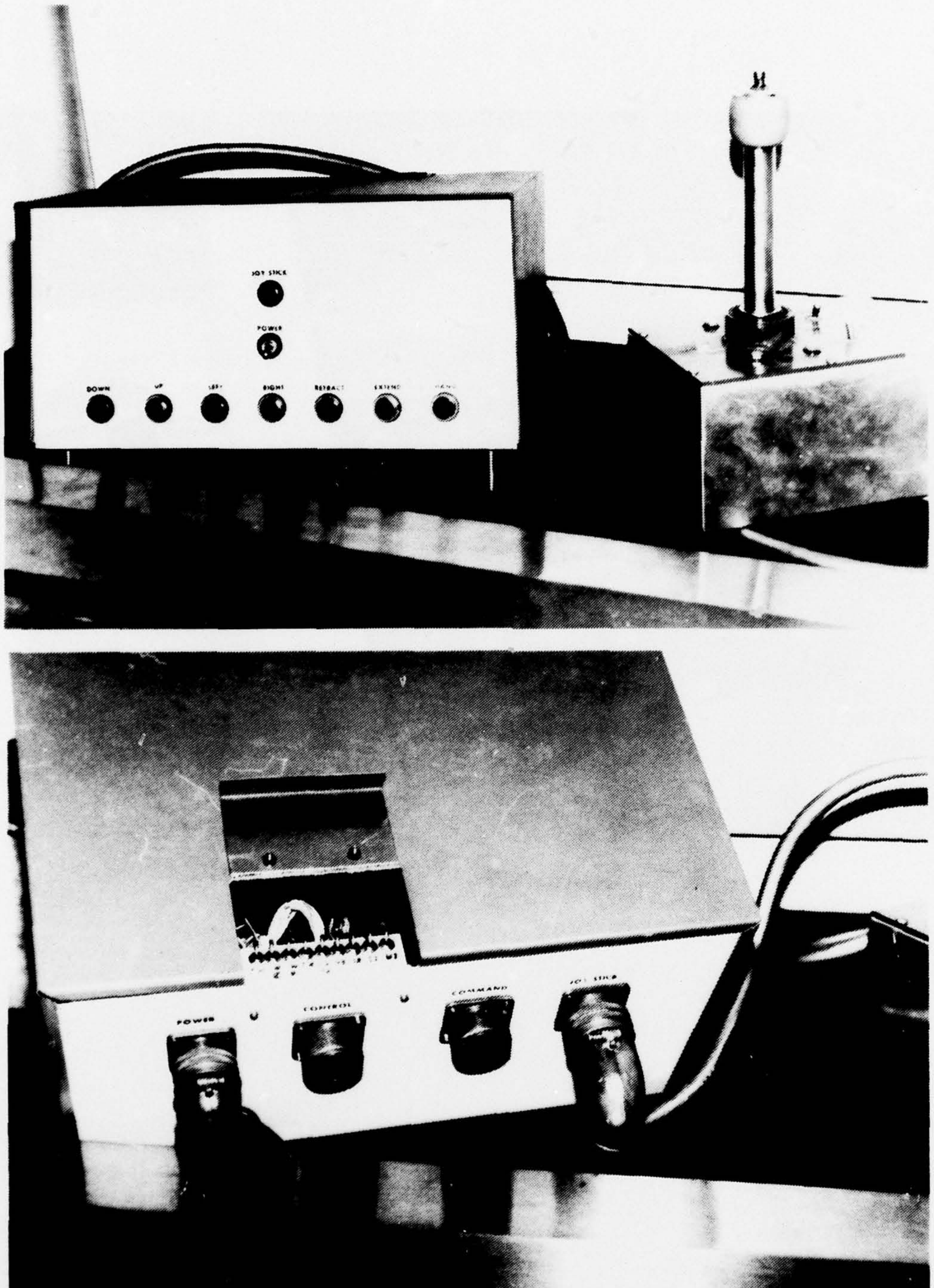

Figure 14. (Above) packaged electrical relay unit and joy-stick arm control; (below) built-in toggle switches used for simulating pickup mechanism position.

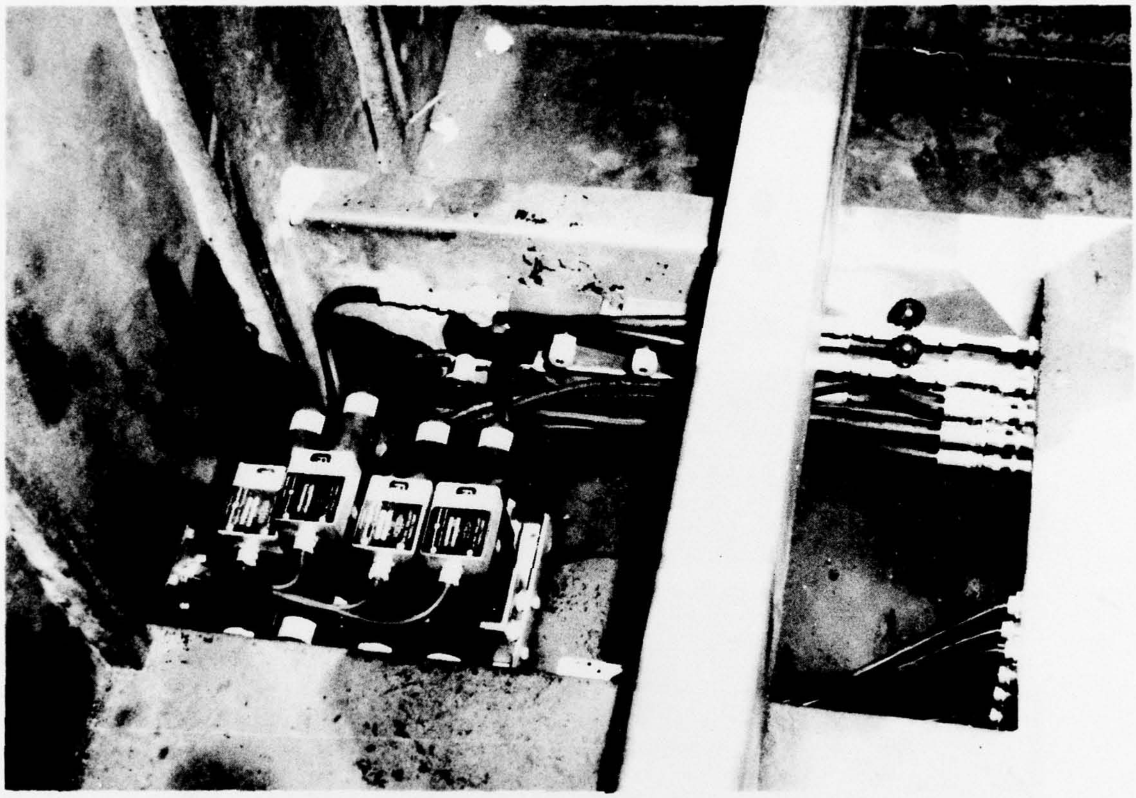

Figure 15. Hydraulic valves located in compartment on floor of bin.

Table 1. Comparison of FY-76 Laboratory Test Results With Principal Design Criteria for a Mechanical Collection Attachment

Criteria	Desired Characteristics	Test Results With First Prototype
Container		
Present:	Container of opportunity	See "Container Grasping" criterion.
Future:	Sized for storage of household refuse in standardized, single container of capacity equal to maximum quantity generated weekly.	See "Arm" and "Container Grasping" criteria.
Cycle time	Minimal (12 to 18 sec)	17 to 21 sec
Arm		
Capacity	150 lb (68 kg)	150 lb (68 kg)
Reach	7 ft (2.1 m)	6.6 ft (2.0 m)
Swing	45 deg (0.79 rad)	47 deg (0.82 rad)
Container grasping	Capable of picking up existing containers of a vareity of shapes and sizes.	Adaptive hand grasped and did not damage a filled 40-gal (0.15-m^3) plastic bag, an empty cardboard box, and a 45-gal (0.17-m^3) refuse can.
Bin size	6 cu yd (4.6 m^3)	5 cu yd (3.8 m^3)
Crew size	One man	One man
Human energy	Minimize human energy requirements (available 2,400 k-cal per 8 hr man-day). Should not require more than 1,200 k-cal.	Not evaluated.
Climate	Unaffected by climate extremes.	Not evaluated.

continued

Table 1. Continued

Criteria	Desired Characteristics	Test Results With First Prototype
Maneuverability	Unconstrained by conditions of collection area [outside turning radius - 36 ft (11 m) or less].	Truck turning radius not altered.
Truck modifications	No major modifications.	Only cab controls and several hydraulic components required on truck for functioning of attachment.
Flexibility	Quick on/off attachment or permanently mounted so as not to hinder primary truck functions.	On/off each requires no more than 10 min.

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NAVFACENGCOM - CHES DIV. Code 101 Wash, DC; Code 402 (R. Morony) Wash, DC; Code 405 Wash, DC; Code FPO-1SP (Dr. Lewis) Wash, DC; Code FPO-1P12 (Mr. Scola), Washington DC
NAVFACENGCOM - LANT DIV. RDT&ELO 09P2, Norfolk VA
NAVFACENGCOM - NORTH DIV. (Boretsky); (Boretsky) Philadelphia, PA; Code 1028, RDT&ELO, Philadelphia PA; Code 114 (A. Rhoads); Design Div. (R. Masino), Philadelphia PA; ROICC, Contracts, Crane IN
NAVFACENGCOM - PAC DIV. Code 402, RDT&E, Pearl Harbor HI; Commander, Pearl Harbor, HI
NAVFACENGCOM - SOUTH DIV. Code 90, RDT&ELO, Charleston SC; Dir., New Orleans LA
NAVFACENGCOM - WEST DIV. AROICC, Point Mugu CA; Code 04B; Code 114C, San Diego CA; RDT&ELO Code 2011 San Bruno, CA
NAVFACENGCOM CONTRACT Code 09E, TRIDENT, Bremerton WA; Eng Div dir, Southwest Pac, Manila, PI; OICC/ROICC, Balboa Canal Zone; ROICC LANT DIV., Norfolk VA; TRIDENT (CDR J.R. Jacobsen), Bremerton WA 98310
NAVFORCARIB Commander (N42), Puerto Rico
NAVHOSP LT R. Elsbernd, Puerto Rico
NAVOCEANO Code 1600 Bay St. Louis, MS; Code 3408 (J. Kravitz) Bay St. Louis
NAVOCEANSYSCEN Code 7511 (PWO) San Diego, CA
NAVORDSTA PWO, Louisville KY
NAVPETOFF Code 30, Alexandria VA
NAVPETRES Director, Washington DC
NAVPGSCOL Code 2124 (Library), Monterey CA; E. Thornton, Monterey CA
NAVPHIBASE CO, ACB 2 Norfolk, VA; Code S3T, Norfolk VA
NAVRADRECFAC PWO, Kami Seya Japan
NAVREGMEDCEN Code 3041, Memphis, Millington TN; SCE (LCDR B. E. Thurston), San Diego CA
NAVSCOLCECOFF C35 Port Hueneme, CA; C44A (R. Chittenden), Port Hueneme CA; CO, Code C44A Port Hueneme, CA
NAVSEC Code 6034 (Library), Washington DC
NAVSECGRUACT PWO, Edzell Scotland; PWO, Puerto Rico
NAVSHIPYD Code 202.5 (Library) Puget Sound, Bremerton WA; Code 400, Puget Sound; Code 400.03 Long Beach, CA; Code 404 (LT J. Riccio), Norfolk, Portsmouth VA; Code 410, Mare Is., Vallejo CA; Code 440 Portsmouth NH; Code 440, Norfolk; Code 440.4, Charleston SC; Code 450, Charleston SC; Commander, Vallejo, CA; L.D. Vivian; PWD (Code 400), Philadelphia PA; PWD (LT N.B. Hall), Long Beach CA; PWO, Mare Is.; PWO, Puget Sound; SCE, Pearl Harbor HI
NAVSTA CO Naval Station, Mayport FL; CO Roosevelt Roads P.R.; Engr. Dir., Rota Spain; Maint. Div. Dir/Code 531, Rodman Canal Zone; PWD (LTJG P.M. Motodlenich), Puerto Rico; PWO Midway Island; PWO, Keflavik Iceland; PWO, Mayport FL; PWO, Puerto Rico; ROICC, Rota Spain
NAVSUPPACT CO, Brooklyn NY; CO, Seattle WA
NAVSURFWPNCEN PWO, White Oak, Silver Spring, MD
NAVTECHTRACEN SCE, Pensacola FL
NAVWPNCEN Code 7002, E. A. Walker, China Lake, CA
NAVWPNCEN PWO (Code 26), China Lake CA

NAVWPNSTA ENS G.A. Lowry, Fallbrook CA; Maint. Control Dir., Yorktown VA; PW Office (Code 09C1) Yorktown, VA; PWO Yorktown, VA
NAVWPNSUPPCEN Code 09 (Boennighausen) Crane IN
NAVEDTRAPRODEVCEN Tech. Library
NAVFACENGCOM - LANT DIV. Eur. BR Deputy Dir, Naples Italy
NAVSUBASE ENS S. Dove, Groton, CT; LTJG D.W. Peck, Groton, CT
WPNSTA EARLE Code 092, Colts Neck NJ
NCBC CEL (CAPT N. W. Petersen), Port Hueneme, CA; CEL AOIC Port Hueneme CA; Code 10 Davisville, RI; PW Engrg, Gulfport MS; PWO (Code 80) Port Hueneme, CA
NCR 20 Code R31; 20, Commander
NMCB 133 (ENS T.W. Nielsen); 5, Operations Dept.
NROTCU Univ Colorado (LT D R Burns), Boulder CO
NSC CO, Biomedical Rsch Lab, Oakland CA; Code 54.1 (Wynne), Norfolk VA; Code 703 (M. Miller), Pearl Harbor HI
NTC OICC, CBU-401, Great Lakes IL; SCE Great Lakes, IL
NUSC Code EA123 (R.S. Munn), New London CT; Code 131 New London, CT
OCEANAV Mangmt Info Div., Arlington VA
OCEANSYSLANT LT A.R. Giancola, Norfolk VA
OFFICE SECRETARY OF DEFENSE OASD (I&L) Pentagon (T. Casberg), Washington DC
ONR Code 700F Arlington VA
PACMISRANFAC CO, Kekaha HI
PMTC Pat. Counsel, Point Mugu CA
PWC ENS J.E. Surash, Pearl Harbor HI; ACE Office (LTJG St. Germain) Norfolk VA; CO, Great Lakes IL; Code 116 (LTJG. A. Eckhart) Great Lakes, IL; Code 120C (Library) San Diego, CA; Code 200, Great Lakes IL; Code 220 Oakland, CA; Code 220.1, Norfolk VA; Code 30C (Boettcher) San Diego, CA; Library, Subic Bay, R.P.; XO Oakland, CA
SPCC PWO (Code 120) Mechanicsburg PA
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USCG (G-ECV/61) (Burkhart) Washington, DC
USCG ACADEMY LT N. Stramandi, New London CT
USCG R&D CENTER LTJG R. Dair, Groton CT
USNA Energy-Environ Study Grp, Annapolis, MD; Environ. Prot. R&D Prog. (J. Williams), Annapolis MD; PWD Engr. Div. (C. Bradford) Annapolis MD; PWO Annapolis MD; Sys. Engr Dept (Dr. Monney), Annapolis MD
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CANADA Surveyor, Nenninger & Chenevert Inc., Montreal; Warnock Hersey Prof. Srv Ltd, La Sale, Quebec
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